Demo Abstract: Welcome to My World: Demystifying Multi-User AR with the Cloud

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ABSTRACT

We demonstrate multi-user persistent Augmented Reality (AR) on mobile devices with a novel technique that provides nearly instant acquisition of location and orientation. Visual Inertial Odometry (VIO) provides accurate position and orientation tracking relative to device start-up for AR applications. Unfortunately, the tracking is local to the AR session of a single user and is not anchored in a global coordinate system. In order to provide all devices an accurate location in a common frame of reference, we utilize UWB nodes that range to the devices. To avoid the long startup time required to compute the device's orientation, we propose a novel technique that utilizes previously recorded magnetic field information to rapidly calibrate the compass. In order to simplify setup, we demonstrate automatic mapping of beacon locations and surveying of magnetic field by a pedestrian walking around the test area with a mobile device.

1 INTRODUCTION

Recently, we have seen a rapid growth in the platforms and devices that support AR and VR, and a corresponding growth in the user applications. AR and VR systems have the potential to revolutionize the way we interact with our environments. Over the past year, the emergence of Apple's ARKit and Android's ARCore have made AR a reality in mobile devices.

These APIs currently enable (1) VIO-based tracking, (2) scene understanding and (3) rendering on mobile devices. However, the AR experience on mobile devices is limited [1] due to the lack of the following features:

(1) Persistent session
(2) Multi-user interaction

This is due to the frames of reference used by ARKit and ARCore. The frame of reference of a session is defined with respect to the device's initial location and orientation when the AR session was started. The device's pose (3D location and orientation) is local to the session. Objects rendered in a session are associated with this local (to the current session) coordinate frame. Hence, once the application is closed and reopened, the previously rendered objects are no longer rendered at the same location. This also inhibits multi-user interaction since multiple-users in the same physical space have different frames of reference with respect to their own devices. Current phone-based AR systems lack the capability to store data that is persistent in its location over multiple user sessions across multiple devices.

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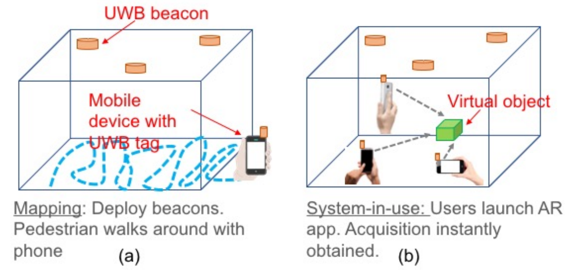


Figure 1: Overview of demo

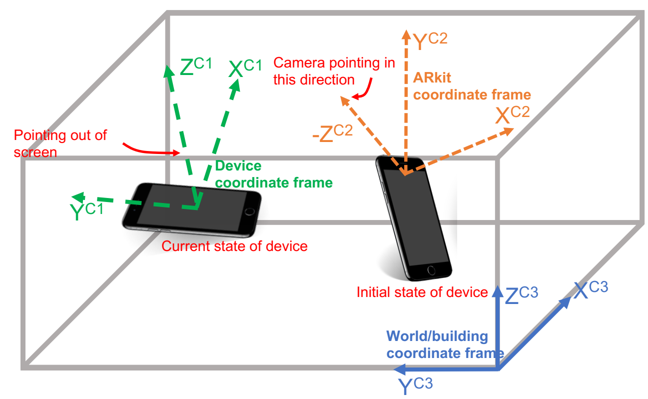
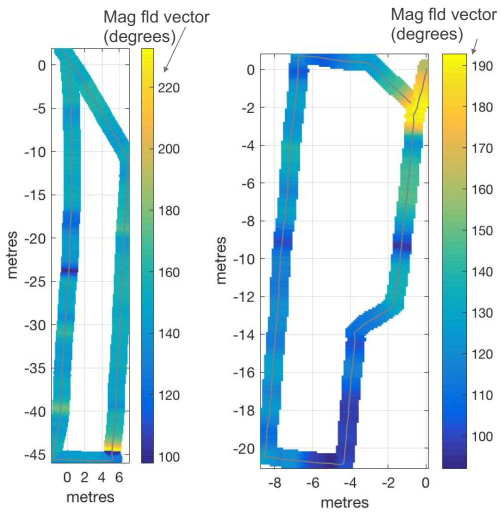


Figure 2: Different coordinate frames: C1 (device), C2 (AR), C3 (world)

We demonstrate a system that **enables persistent AR data on mobile devices across multiple devices over time, in an indoor environment.** This is a proof-of-concept for our vision of bringing the capabilities of expensive AR headsets to commodity off-the shelf mobile devices, to enable a range applications that do not exist today.

2 SYSTEM DESCRIPTION

Goal: The goal is to estimate the pose of the device in the world coordinate frame instantly. Fast time-to-first-fix of location and orientation is a hard requirement for an AR system. A delay in location service would cause the device to render the scene incorrectly, resulting in an unpleasant user-experience.



(a) Garage (a) Bookstore

Figure 3: Magnetic field map of real world environments

We define three frames of reference shown in Figure 2:

(1) $C1$: Device frame of reference
(2) $C2$: AR frame of reference
(3) $C3$: World frame of reference

$C1$ is the frame of reference fixed with the device. All inertial sensors (accelerometer, gyroscope, magnetometer) are read with respect to this frame. $C2$ is the frame of reference defined by ARKit. ARKit coordinate system is such that the system's y-axis is parallel to gravity, and z axis points in a direction determined at start of the AR session, such as the direction of camera. $C3$ is the global coordinate frame. It can be set by the system installer to align with the building map or GPS coordinates. In summary, frame $C1$ moves with the device, frame $C2$ is fixed for an AR session, and frame $C3$ is fixed over all time and the goal is to transform the AR coordinate frame to the global coordinate frame.

Sensor inputs: We use the following sensor data from the mobile device: 3D magnetic field (in $C1$), 3D position and orientation (in $C2$) from ARKit, range from beacons, and the data generated in the mapping process.

Mapping process: The output of the mapping process is the beacon locations in $C3$ and the 2D (horizontal component, perpendicular to gravity) magnetic field vector in $C3$.

Overview of solution: We acquire the location of the device by fusing the range measurements from beacons and position updates from VIO. The main innovation of our approach is to acquire the orientation using the magnetic field. The magnetic field is measured in $C1$. We transform the magnetic field to the ARKit frame of reference $C2$ using the device's orientation from ARKit. The magnetic field map provides us the magnetic field in $C3$. By computing the rotation between the mapped magnetic field and the measured magnetic field, we estimate the rotation of $C2$ with respect to $C3$. Hence, we acquire the orientation of the device in $C3$ instantly.

Leveraging magnetic field for orientation: ARKit API allows the device to use the heading or compass to acquire the frame of reference for a session. Assuming the compass always points towards North at all times at all locations, we can rely on this for acquiring the same orientation in every session. However, in indoor environments, the magnetic field is affected by the building structure and materials in the environment. The field can fluctuate drastically across locations. Several prior work have shown the magnitude to be stable over time [2] and we experimentally verify that the angle of magnetic field is also stable over time. Figure 3 shows the spatial variation in the angle of magnetic field in a garage and a bookstore. If we rely on the compass for the orientation, the error can be as high as $120°$ between the frame of reference obtained at two locations. However, we can map the magnetic field at all locations before-hand and subsequently use this map as a reference. Our proposed mapping process, which was used to generate the maps shown in Figure 3 required a pedestrian to simply walk in the indoor space with a phone held in hand.

Infrastructure: Our proposed system includes localization beacons capable of time-of-flight ranging (UWB, BLE, Ultrasonic), and a smart phone. We deploy four UWB beacons around the demo area. Since mobile devices are not compatible with UWB, we attach a UWB-Raspberry Pi Zero W device to the back of the mobile device, powered by an external battery. We envision that in future commodity mobile devices will be capable of time-of-flight RF ranging to WiFi APs (using 802.11ax) or beacons deployed for indoor localization (using Bluetooth 5). AR systems can leverage this localization capability without incurring any additional cost.

3 DEMONSTRATION

Our demonstration has two phases: (1) mapping and (2) AR demo. The overview of the demo is shown in Figure 1. During the mapping phase, UWB beacons are deployed in the demo area. A pedestrian then walks around with a mobile device. We run our mapping algorithms which estimate the location of the beacons with respect to some global coordinate frame and the vectored magnetic field map of the demo area. The second phase is the system-in-use or AR demo phase. During this phase, a device starts an AR session and our localization and orientation estimation algorithm instantly estimates the device's location and orientation in the global coordinate frame. This algorithm runs off each device independently and the devices are now capable of interacting with virtual objects in the environment that persist over time. The application demo (on iOS devices) would involve one user placing a virtual object in the environment and subsequently other users interacting with this object.

ACKNOWLEDGMENT

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